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PINE TIP MOTH ON THE NEBRASKA NATIONAL FOREST

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INDEX

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INTRODUCTION

The moths belonging to the genus Rhyacionia Hubner[1], commonly called the pine tip moths, are important enemies of pine trees of seedling and sapling size, attacking practically all of the two and three-needled species. The larvae bore into the buds and down through the new shoots, confining their work to the current year's growth. This type of injury seldom kills fast-growing trees, the damage resulting in retarded growth and deformed trees; however, individuals with poor vigor may succumb to repeated destruction of the new growth. Injury gradually decreases after the trees are well above sapling height if growth continues vigorous.

Damage by different species of tip moths has been reported from many sections of the United States in late years. The recent observance of this type of injury in certain localities where it has not been reported before is perhaps due to the increased attention given young stands of pine, although epidemics are evidently more or less sporadic in certain sections. On the other hand, there has very likely been a general increase in tip moth damage as a result of favorable environments

(1) For description and key to different species see U.S. National Museum Bulletin 123, "Revision of the North American Moths of the Subfamily Eucosminae of the Family Olethreutidae", by Carl Heinrich, 1923.

created by extensive stands of reproduction following cutting. This is known to be particularly true where large areas of pure pine plantations have been established, as is the case on the Nebraska National Forest.

The Nebraska National Forest is entirely man-made. It is situated in the sand hill region of Nebraska and the plantations on the Dessey Division, near Halsey, comprise some 15,000 acres of pine planted during the last 25 years. Rhyacionia frustrana bushnelli Busck, a variety of the common eastern tip moth, was first discovered in the plantations in 1909, and since that time has been a continued serious menace to the growth of the forest. Western yellow pine, the most extensively planted and valuable species, is very seriously damaged and in some years in plantings of the most susceptible size over 90 per cent of all terminals and 70-80 per cent of all lateral tips are infested by tip moth larvae. The injury to individual tips varies from the destruction of a few buds to the complete riddling of the entire shoot. The few plantings of Norway pine are equally susceptible and apparently have been partially exterminated as a result. Jack pine, the second species in abundance, is less severely attacked and the numerous laterals readily replace the damaged terminals. Scotch pine is slightly less susceptible than jack pine, and Austrian pine is immune to serious infestation.

Investigations concerning the pine tip moth have been conducted by the Bureau of Entomology during the past four seasons, in cooperation with the U. S. Forest Service, and most of the work has been confined to the Nebraska plantations.

THE 1928 WORK IN GENERAL

The investigations in 1928 were continued on the Nebraska National Forest, at Halsey, Nebr., during the entire field season with the exception of about a month in May and early June spent by the writer in Arizona studying the biology of the tip moth and its parasites in that region. Mr. Randal Nichols assisted with the work in Nebraska during the last half of the season.

The various phases of the work on this project might be summarized in the order followed in this paper: experiment with control by parasite concentration; dipping nursery stock, and tests with various insecticides as dips; field spraying; observations on life history and damage; study of parasitism, including progress of introduced parasite; inspection of private plantations and native timber to determine distribution of tip moth; observations on two tip moths new at Halsey; and records of other forest insects that have entered the plantations of the Nebraska Forest. The report also includes besides the 1928 data some observations and experiments which have not been recorded in formal reports of previous years. The 1927-1928 data on dipping nursery stock complete in detail the reporting of experiments conducted in early spring for the past four years[2] to find a cheap and efficient method of destroying tip moth eggs on nursery stock before shipment in order to prevent the spread of the pest in this stage.

(2) The 1925 and 1926 experiments with insecticides and experiments with hot water submitted as manuscripts for publication in *Jr.Ag.Research* in co-authorship with Dr. E.A. Graham -- not yet published.

The work conducted in Arizona and southern Colorado will not be given in detail in this report but it might be well to mention a few interesting observations at this point. The tip moth found to be prevalent in the region was one of the western species, Rhyacionia neomexicana Dyar. A few adults were taken in yellow pine at the Fort Valley Forest Experiment Station, near Flagstaff, Ariz., on May 14, 20, and 21, but these were probably some of the late emerging moths. From the character of the damaged tips there is apparently but a single generation each year. Damage is not as severe as on the Nebraska Forest, but the growth and form of yellow pine are often considerably impaired. Although the common tip moth in Nebraska, R. frustrana bushnelli, was originally described from material taken in the plantations at Fort Bayard, N. Mex., no definite evidence was found of its presence in the vicinities of Flagstaff and Prescott, Ariz. However, winter rearings may possibly give some evidence of this species. Several other moths were also found attacking the new growth of yellow pine, although not as prevalent as the tip moth.

A new species, Eucosma sonomensis Busck, just recently described (3), was reared from the new growth tips collected on the Prescott National Forest in Arizona, the moths issuing between June 22 and July 16. This moth is small, 13-15 mm. alar expanse, gray, with a predominating black streak along the center of the forewings. The small

(3) Proceedings of Ent.Soc. of Washington, Vol. 31, No. 1, Jan., 1929, "A New Injurious Pine Moth (Lepidoptera: Gelechiidae)", by August Busck.

yellow larvae found abundant and burrowing in the tips of small yellow pine near Cross Creek Ranger Station on the Prescott Forest were presumably this species, but near the city of Prescott these larvae were very scarce. They were common in some trees examined near Lake Mary on the Coconino Forest but were uncommon at other points in the immediate region. A few adult specimens issued from tips collected by the writer at Williams, Ariz., and from tips collected later near Fort Valley Forest Experiment Station by Mr. R. F. Copple, Junior Ranger Examiner.

The larvae of a much larger moth were found burrowing up through the new shoots of sapling yellow pine in these same localities but were most prevalent on the Prescott Forest. A few had already pupated in early June and adults emerged from collected material between June 28 and July 16. Specimens sent to Mr. Carl Heinrich were determined as Pinipestis sp., with a single specimen of Marmara sbistella D. & S. in the collection.

Tip moth damage reported on the San Juan Forest of southern Colorado was investigated and the young larvae found in the tips in early June were those of Rhyacionia neomexicana. The identity of the species has been checked by the rearing of a few adults this winter. Somewhat of an epidemic was in progress on an area, in which heavy reproduction had followed clear cutting, some four miles east of the Yellow Jacket Ranger Station, near the Piedra River. Ranger Loring stated that damage on this area was quite severe several years ago, and from the number of young larvae present last spring many of the terminals and laterals were doomed to partial destruction. A note received from the Forest Service states

that the timber survey crew working in this same locality last summer reported the tip moth "in yellow pine reproduction on the Elk Creek logging unit and along the Durango highway". Young larvae were also found in yellow pine near Durango, headquarters of the San Juan Forest, and no doubt evidence of the insects' presence might be found over the entire region. It is not unlikely that in extensive stands of reproduction this pest will be found in epidemic proportions at some time. It is hoped that rearings this winter, from tips collected when the larvae were full grown, by Mr. W. P. Apgar, Administrative Assistant on the San Juan, will give information on the parasites attacking the tip moth in this locality.

RESULTS OF 1927 PARASITE CONCENTRATION

To test the effect of concentrating a large number of parasites on limited areas in the plantations of the Nebraska Forest, tip-moth infested tips were caged in yellow pine above the nursery in 1927. About 110 bushels of tips collected during an experiment with mechanical control, at the time of pupation of first-brood larvae, were placed in four large frame, screen-topped cages, which would retain the moths but permit the escape of practically all species of parasites. These parasites would necessarily have to attack the larvae of the second brood tip moth or other hosts.

About the only method of analyzing the influence of this concentration seemed to be the comparison of the abundance of parasites and moths from the trees near the cages with that of other collection plots when rearings were completed the following season,- in 1928. This would indicate whether the parasites had multiplied and maintained the increase over winter. A reduction in the abundance of moths would also imply that many of the larvae had been destroyed. A check on amount of damage to the trees following second-brood injury would have been of little use, since many of the larvae complete their feeding, or nearly so, even when parasitized.

Table 1 gives the per cent of parasitism as shown by rearings from infested tips collected near the four large concentration cages, or plots as they will be called, compared to the parasitism from other widely scattered tip collection plots in yellow pine. The total number of insects is reduced to a basis of 100 tips and includes both moth and parasites, the per cent of local parasites being the proportion of this total number. The introduced parasite, Compsilura frustranea Cushman, was the most abundant species reared from many of the collection plots in 1928. This species, however, was not in the tips caged in the field, not having spread to the areas where the mechanical control experiment was carried on and consequently only the local or native parasites should be recognized. By considering all Compsilura as potential moths, a fairly accurate figure of parasitism by the local species is obtained. This is discussed further under parasites.

Table 1

Abundance of insects and per cent parasitism by local parasites in yellow pine at parasite concentration plots as compared to all other collection plots, 1928 (Cenocoelex considered as potential moths).

Plots	Number of Tips Collected	Aver. all Insects per 100 Tips and Range Single Plots	Per Cent Local Parasites and Range for Single Plots
4 concentration plots	1200	109.5 (73.0 - 143.3)	10.0 (4.4 - 15.7)
13 other plots as check	3300	133.2 (105.3 - 199.0)	9.8 (2.2 - 15.0)

The per cent of local parasites near the cages, attacking the first brood in 1928 as indicated in Table 1, is not appreciably higher than the average of all other plots. It is apparent that if the local parasites emerging from the large concentration cages in 1927 did heavily parasitize the second-brood larvae this advantage was lost in overwintering. It appears that the number of insects in the infested tips, indicating abundance of larvae, had been reduced in the vicinity of the cages, but when the great variation between individual plots is noted this must be partially discounted.

Before the tips were caged for the experiment in 1927 parasite material was collected at two of the concentration plots. Local parasitism was very low in this material, only 3.4 per cent as compared to 7.7 per cent in all other yellow pine plots. Possibly the additional parasites helped to bring this per cent up to normal in 1928. It is

apparent that the influence of concentrating the native parasites under conditions found in the Nebraska plantations is of little practical value.

The mechanical control experiment in 1927 was conducted to determine the cost of cutting the infested tips from trees in young plantations of different ages and the efficiency with which such an operation could be carried on. This method, it was considered, might be used to eliminate the source of infestation over large areas of young plantings not adjacent to old, infested plantations. It was found that with an ordinary crew of boys, even under careful supervision, a few infested tips were always missed because of the difficulty of detecting slightly infested shoots and the bushy character of some of the trees. Even with the impracticability of a complete clean-up by this method there was still the possibility of concentrating parasites from other plantations on the treated area for a year or two following to hold down the infestation and thus by combining the two methods of control afford protection to the trees during a critical period. Parasite concentration, if effective, might have been useful in reducing the amount of infestation in older plantations also and, therefore, the experiment with biological control discussed above was tried.

The experiment with mechanical control[4] demonstrated that in a five-year plantation of yellow pine with 650-700 trees to the acre and averaging a little over a foot in height, the area could be covered at the rate of 2.25 acres per man-day, at a cost of $1.10 per acre, exclusive of supervision; with an average of one infested tip on every fifth tree

(4) Unpublished report, "Experimental Control of the Pine Tip Moth at Halsey, Nebr., 1927".

missed. The larger jack pine of the same age and with a denser stand was much more expensive. In yellow pine ten years old, which were much more bushy, with 550-600 trees to the acre and averaging about two feet in height, only 0.65 acre per man-day was covered, at a cost of $4.00 to the acre; an average of one infested tip for each tree being passed up. The small areas covered were merely to determine the efficiency and costs of the operation, and moths from adjoining trees probably account for the lack of a reduction of infestation by the second brood in proportion to the amount of material removed. The trees from which many tips were cut put out adventitious buds in late summer and the growth in 1928 was equally as good as on other trees.

Since the native parasites failed to take advantage of this opportunity offered them, and since the thousand or so acres planted each year are too extensive to use tip collecting alone as a means of protection, this combined method of mechanical and biological control cannot be successfully used with the present local parasites. However, the concentration of the introduced parasite might have given results, since it attacks the second-brood larvae, winters over in the host cocoons and emerges in increased numbers the following spring. The experience in handling tips and use of cages will be of considerable value in liberating Campoplex in new areas. The mechanical control experiment also gives us an idea of the cost and the difficulty of getting all infested tips. So far this is about the only means of protection open to the owners of small

plantings. The interest in the protection of these private plantings may be a little more general now since the recipient of nursery stock is required to pay at least the cost of growing the transplants.

DIPPING NURSERY STOCK, 1928

As in 1927, all stock shipped from the nursery at the usual time in April, for planting outside the Forest, was dipped to prevent the spread of tip moth in the egg stage. Nicotine oleate was again used at one part of nicotine to 200 parts of solution. The dipping fluid was changed frequently because the accumulation of sand and litter in the bath gradually lessened its insecticidal value, as tests with eggs indicated. (See Table 6). Dipping about 1,000 transplants for each two gallons of dip was considered about the maximum treating that could be safely used.

A total of 340,000 trees, 2-1 stock, were treated. The cost of the operation is estimated at $0.472 per thousand, roughly itemized as follows:

85# Nico Fume @ $1.198 per #	$101.83
7.35 gallons oleic acid @ $1.85 per gal.	13.60
54 hours nursery labor, and meals	17.75
4½ days Bureau of Entomology, and meals	27.24
Total	$160.42

The labor items cover preparation of material and equipment and the actual dipping operation, but does not include any handling of the trees before or after the operation.

TESTS WITH VOLCK AS A DIP

Volck, a white oil emulsion, was first tried in 1927 as a possible cheap dip for nursery stock, and although satisfactory it was considered advisable to give it a more thorough test in 1928 before recommending its use. The summer-spray strengths have proved very satisfactory and Volck at one part to 100 parts of water is now recommended to replace the more expensive nicotine sleate -- the cost of material should be less than 1/10 that of the nicotine solution.

Effect of Volck on Tip Moth Eggs

A series of tests were made with various concentrations of Volck on summer-brood tip moth eggs in 1927 and 1928. The eggs were obtained by capturing moths in the field and confining them in small vials with several pine needles. In each case part of the eggs were kept to check fertility, and the remainder dipped in the solution for less than half a minute, permitted to dry and then again placed in a cotton-plugged vial to check hatching. Eggs of various ages were treated but the stage of development had no influence.

The sand and litter on trees dug in the nursery washes off during dipping and rapidly accumulates in the bath, thus gradually absorbing part of the oil. Therefore, sand was added to 1/3 and equal the volume of some of the solutions to determine its influence on egg killing. Table 2 shows the effectiveness of various dilutions of freshly-mixed Volck on tip moth eggs.

Table 2

Effect of different dilutions of fresh Velck, clean and with sand added, on summer-brood tip moth eggs, 1927 and 1928.

Dilution	Amount Sand Added	Number of Tests	Treated Eggs		Check Eggs	
			Number	% Killed	No.	% Hatched
1 - 32	None	3	68	100	46	95.7
1 - 50	"	3	63	100	42	97.6
1 - 100	"	15	256	100	159	95.0
1 - 125	"	4	95	100	51	94.1
1 - 150	"	4	69	100	46	87.0
1 - 200	"	5	101	100	71	95.8
1 - 100	1/3 volume	9	100	100	55	92.7
1 - 100	equal volume	5	117	99.1	77	88.3

The only failure of 100 per cent kill was in a 1-100 dilution when an equal volume of sand had been added and here only one egg out of the 117 hatched. The smaller amount of sand had no influence and even dilutions of 1-200 of clean Velck killed all eggs.

More eggs were treated in these same mixtures after they had stood open in the Mason jars for one and two days. Although not listed in the table these tests also gave 100 per cent kill with the one exception, the same sample with an equal volume of sand had 4 eggs hatching out of 21 dipped the second day after the solution was mixed, although another test the day following mixing gave 100 per cent kill. Of course, in these small jars the oil, after standing a day or two, was readily shaken into a state of emulsion again when used. However, in a large tank it might be difficult to get the oil into suspension again.

A modification of the Babcock cream test was tried in an attempt to measure the per cent of oil absorbed by the treated trees and accumulated sand in the bath. This proved unsatisfactory because much of the sand and litter remained in the oil layer at the top of the test tube, furthermore, the very small amount of oil in a 1-100 solution could not be readily measured.

To determine the influence of dipping a large number of trees and the point at which the solution is reduced to ineffectiveness against the eggs, 2,600 2-0 yellow pine were dipped in only 2 gallons of Volck 1-100. The last lots of trees were treated two days after the solution was mixed and some of the clean fluid was kept for two days for tests also. Samples of the dip were taken at intervals for treating eggs later and were sealed in Mason jars and kept from late April until eggs were obtained from the first brood in May and the second brood in July. For this reason these tests are separated from the tests with freshly mixed Volck given in Table 2. The number of trees treated, the amount of sand accumulated and added in the bath, and the day on which the samples were taken are given in Table 3, together with the per cent of eggs killed by treating. The influence of this dipping on the trees is given in Table 5.

Table 3

Effect of Volck 1-100 on spring and summer-brood eggs 1923. Samples of dip taken after treating definite number of seedlings in two gallons of solution and kept in sealed jars until eggs available.

Condition when Sample Taken				Treated Eggs		Check Eggs	
No. Trees Dipped	Vol. of Sand	Dip Mixed	No. of Tests	No.	% Killed	No.	% Hatched
None	None	Same day	6	56	100	35	82.9
"	"	2 days previous	5	37	100	59	100.
1200	1/6	Same day	3	28	100	20	85.0
2200	1/3	" "	4	62	95.2	38	86.6
2200	1/3	2 days previous	4	76	100	54	87.0
2600	1/2	"	4	68	100	37	97.3

Only one failure of complete kill occurred in the above tests, this after treating 2,200 seedlings in the two gallons of dip and sand had accumulated and been added to 1/3 the volume of the liquid. Only 3 eggs out of 28 in one of the four tests hatched. This hatching does not look very consistent, since even with sand added to 1/2 the volume all eggs were killed, unless the fact that the material had stood for two days had some influence. The solution was always thoroughly stirred before dipping the trees.

From the two above tables it is apparent that Volck 1-100 is an efficient strength, since even twice this dilution of fresh material killed the eggs, and not until from one-third to an equal volume of sand as compared to the liquid had accumulated in the bath, were there any failures in killing, and these failures were not consistent.

Effect of Volck on Pine Seedlings

All of the treated seedlings discussed in this paper were taken in early spring at the time of digging, divided into lots and immersed in the dipping fluid for 15 to 20 seconds, or just long enough to insure a thorough wetting of all surfaces, permitted to drain for a short time, and then wrapped in heavy paper with the roots in wet shingletow as for shipping. The trees were planted later by the regular transplant crew in the nursery. Check lots were handled in the same way with the exception of dipping. Fall counts gave the survival figures and the number of trees with dead tips for comparison with the check lots.

In 1927 two lots of yellow pine seedlings were dipped in a fairly concentrated solution of Volck, 1-32, to test their susceptibility. In one lot only the tops were dipped, in the other the entire tree, thus subjecting the roots to the diluted oil. Table 4 shows the effect on survival. The trees were left wrapped for only one day before planting.

Table 4

Survival of yellow pine 2-0 seedlings with tops and roots dipped in Volck 1-32 as compared to untreated seedlings.

Number Trees Planted	Part Tree Treated	Per Cent Dead	Per Cent with Tip Injury
200 (check)	Untreated	2.5	1.0
100	Tops	2.0	2.0
100	Roots and tops	7.0	3.0

Comparing the loss in treated trees with normal mortality in untreated lots in Table 4, the data indicate that dipping the tops of seedlings in Volck 1-32 has no detrimental effect. The new tips, just starting to expand but still protected by the bud scales, are not definitely affected by the oil. By immersing the roots also it appears that a few weak individuals were killed by the treatment, although this loss is not heavy.

The 2,600 seedlings dipped in the two gallons of Volck 1-100 to get samples of used dip for testing on eggs, as discussed above, were planted and checked in the usual manner. In some lots the roots were immersed, and the last trees were dipped after the solution had stood for two days; clean Volck two days old was also tested as a check, in all cases being stirred thoroughly before dipping. Table 5 shows the survival and the number of trees with tips injured. These trees were left in the shipping bundles for one and three days before planting.

Table 5

Survival of yellow pine 2-0 seedlings with tops and roots dipped in Volck 1-100 as compared to untreated seedlings.

Day Dipped from Time of Mixing	No. of Trees	Part Treated	Vol. Sand in Bath	% Trees Dead	% with Tips Injured
(5 check lots)	500	Not treated	—	4.2 (Range 2-8%)	4.4 (Range 0-6%)
Same day	1600	Tops	0-1/3	6.0	2.6
" "	600	Roots & Tops	0-1/3	5.7	3.7
Two days	200	Tops	1/2	2.5	1.5
" "	200	Roots & Tops	1/2	3.5	1.5
" "	200	Tops	None	9.0	8.0
" "	200	Roots & Tops	"	9.0	5.0

From the above table it is apparent that Volck 1-100 does not injure nearly dormant seedlings even when the roots are immersed, the mortality and number with dead tips coming within the range of normal loss as shown for the five check lots, or so near as to have little significance. No loss from Volck at this dilution would be expected, since even at 1-32 there was little influence on the trees. A 1-100 dilution could no doubt be used on the tops of growing seedlings without injury to the trees.

Recommendations for Use of Volck

Volck at 1-100 should make a very efficient dip for nursery stock. Absorption by the trees and sand might reduce the oil to half this amount and still be effective in killing tip moth eggs, according to the experimental results. Because of this absorption the solution will have to be changed for fresh material at intervals. An average of 1,000 transplants to each gallon of dip should leave a safe margin, the accumulation of sand would be less than one-third the volume of the liquid and all eggs were killed under similar conditions; in fact most eggs were destroyed under less favorable conditions. This could be handled by using common wash boilers or similar deep containers as dipping tanks. In 10 gallons of the dip some 10,000 trees could be treated, the boiler emptied and fresh material mixed as needed. It is inadvisable to prepare a large quantity of Volck and let it stand for a day or two. Any oil that has "creamed" to the top should always be thoroughly stirred into the solution before dipping the trees. At the above proportions one gallon of Volck will make 100 gallons of dipping fluid and treat some 100,000 transplants of 2-1 stock. The retail price of Volck is about $3.00 for a gallon can.

CONTINUED EXPERIMENTS WITH OTHER INSECTICIDES

Experiments with some of the other promising insecticides were continued in 1927 and 1928 to check previous tests. Although these materials will not be used, the results are summarized in this report to put them on record.

Nicotine oleate

The following tests with eggs show again, as in 1926, that nicotine oleate at 1 part nicotine to 300 fails to destroy all eggs, while 1-200 is sufficiently strong. The dipping of a large number of trees seems to weaken the mixture as tests with samples, taken from the dipping tanks during the treatment of nursery stock, failed to give the usual kill of eggs. These samples kept sealed in Mason jars until eggs were obtained appear to be a proper test since those from clean dip gave the usual 100 per cent kill. The tests with eggs, both with the sealed samples and fresh mixtures, are given in Table 6. The hatching of some eggs after treating some 1,000 trees for each two gallons of dip was the reason for changing the solution at these intervals, as noted above under discussion of dipping nursery stock.

Table 6

Effect of fresh and used nicotine oleate on summer-brood tip moth eggs. 1927, 1928.

Dipping solution			Treated Eggs		Check Eggs	
Concentration free nicotine	Condition	No. of Tests	No.	% Killed	No.	% Hatched
1-300	Clean	3	24	75.0	17	82.4
1-200	"	12	156	100.0	123	96.7
1-200	Used *	4	41	95.1	33	100.0
1-200	Used **	3	39	71.8	37	94.6

* (Sample in which eggs dipped taken from tank after 5,000 transplants dipped in 12 gallons of solution).
** (Sample in which eggs dipped taken from tank after 5,000 transplants treated in 10 gallons of solution).

A series of tests with three species of pine seedlings were conducted in 1927 to determine the influence of dipping the entire tree and only the tops in nicotine oleate 1-200. Most of these trees were 2-1 stock, with several lots of 2-0 stock, all handled in the usual way and put in transplant beds. These were treated over a period of 10 days and all planted together, meaning that some were left wrapped in the bundles for nine days, other lots for seven days and one day. The long period in these bundles seemed to have a detrimental effect on trees with roots immersed. These tests are summarized in Table 7.

Table 7

Survival of different species of pine seedlings with tops and roots dipped in nicotine sleate 1-200 and left wrapped in shipping bundles from 1-9 days, as compared to untreated seedlings.

Age of Stock	Condition of Solution	No. Trees Planted	Part Tree Treated	% Trees Dead	% with Tip Injury	No. Days Wrapped
		Western Yellow Pine				
2-0 (check)	—	200	Untreated	2.5	1	1
2-0	Clean	50	Tops	0	2	1
2-0	"	50	Roots and tops	4	2	1
2-1 (check)	—	100	Untreated	6	5	9
2-1	Clean	100	Tops	12	5	9
2-1	"	100	Roots & tops	27	10	9
2-1	"	50	Tops (3 minutes)	4	6	9
2-1	"	50	Roots & tops (3 minutes)	48	12	9
2-1	Used *	50	Tops	0	2	9
2-1	Used *	50	Roots & tops	6	2	9
		Jack Pine				
2-1 (check)	—	50	Untreated	4	2	7
2-1	Clean	50	Tops	6	2	7
2-1	"	50	Roots & tops	18	4	7
		Scotch Pine				
2-1 (check)	—	50	Untreated	0	4	7
2-1	Clean	50	Tops	0	2	7
2-1	"	50	Roots & tops	2	4	7

*(4500 transplants dipped in 10 gallons of solution before these lots treated; considerable sand and litter accumulated in tank).

Treating the roots in nicotine oleate 1-200, as shown in Table 7, caused slightly higher mortality in every case than dipping tops only, and trees left wrapped for seven and nine days showed a serious loss, except in Scotch pine. In one case where the entire trees were soaked in the bath for three minutes the mortality was 48 per cent, but with only the foliage submerged the loss was not up to the normal as indicated in the check lot. Lots treated in the 10 gallons of solution in which considerable sand and litter had accumulated from previously dipping 4,500 transplants of 2-1 stock indicates, as with the eggs, that the toxicity of the dip decreases after a large number of trees are treated; the loss in these lots, even with the roots immersed and wrapped for nine days, is not greater than the normal mortality check for 2-1 yellow pine.

These continued experiments with nicotine oleate 1-200 show that it has disadvantages as a dip for nursery stock. The high cost was due largely to the necessity of using fresh material at such frequent intervals. This insecticide, if used on roots of nearly dormant seedling conifers, may cause a loss above normal, and when trees are packed for a week or more in shipment this loss may be serious. Of course, it is not necessary to treat the roots for tip moth eggs, and for dipping only foliage the material was fairly satisfactory except for its cost.

Volck at 1-100 is more satisfactory in all these respects, much cheaper, more trees treated in an equal amount of dip, and apparently no damage even when roots are immersed, although trees have not been left in the bundles for over three days.

Miscible Oil and Volck-nicotine

Miscible oil at 1-15, although a favorable dip, does not give consistent results on treated eggs as is shown in Table 8, and as has been indicated by a few similar failures in previous years. The Volck 1-100 plus nicotine 1-300 kills the eggs as might be expected after the results with Volck alone at this strength have been seen.

Table 8

Effect of miscible oil (Sunoco) and Volck plus nicotine on summer-brood tip moth eggs.

Dipping material and strength	No. of Tests	Treated eggs		Check eggs	
		No.	% Killed	No.	% Hatched
Miscible oil 1-20	3	38	84.2	34	94.1
" " 1-15	3	66	98.5	41	92.7
Volck 1-100 plus nicotine 1-300	4	71	100.0	43	90.7

The above two materials used on the roots of seedlings, as shown in Table 9, possibly caused the death of a few weak trees, but loss from treating foliage only is not enough above normal to indicate definite chemical injury. These lots of trees were only left wrapped in the bundles for one day.

Table 9

Mortality in 2-0 yellow pine seedlings with tops and roots dipped in miscible oil (Sunoco) and Volck plus nicotine as compared to untreated trees.

Dipping material and strength	No. of trees	Part tree treated	% trees dead	% with tip injury
(Check)	200	Untreated	2.5	1
Miscible oil 1-15	100	Tops	1.0	0
" " 1-15	100	Roots and tops	6.0	1
Volck 1-100 plus nicotine 1-300	100	Tops	4.0	5
Volck 1-100 plus nicotine 1-300	100	Roots and tops	6.0	5

FIELD SPRAYING WITH MOLASSES-NICOTINE

Molasses or some sticky spray was suggested as a possible means of trapping moths alighting on trees or of preventing oviposition, since molasses has been successfully used against the boxwood leaf miner. Ordinary cooking molasses only slightly diluted was used since the heavier stock-feed molasses was not available. Spraying in April and early May demonstrated that under the dry, windy Nebraska conditions the molasses did not last more than a day or two, except where it had collected between needles or in drops on the surface. Several moths were found held by the wings in drops of molasses soon after spraying, but outside of this the substance was not sufficiently sticky to hold insects of this size. While the trees were still wet the usual activity

of the moths was somewhat hindered but, of course, this condition did not prevail for long. Most of the spring spraying was done before the moths were abundant in the field, the writer being absent during the height of emergence, and consequently a check of damage to these trees showed no definite results.

In spraying plots for the summer brood nicotine was added to the molasses for most of the plots. The nicotine, it was thought, might act as a repellent to the adults, kill the eggs, or kill the newly hatching larvae trapped in the molasses. Owing to the long flight period the trees were sprayed two and three times, except in one case of a single late application to check which stage of the insect was being affected. The per cent of tips infested by the second brood in sprayed plots as compared to unsprayed trees is given in Table 10, and the abundance of different stages of the insect at time of treatment is noted beneath.

Table 10

Per cent of tips infested by second-brood tip moth in yellow pine sprayed with molasses and molasses-nicotine as compared to unsprayed trees.

Plot No.	No. of Trees	Year Planted	Av. ht. Inches	Spray material and strength	Dates* Sprayed	% Terminal tips infested	% Lateral tips infested
Check on III & IV	100	1923	14	(Not sprayed)	--	58	35
III-A	49	1923	15	Molasses 1-2	July 12 July 23	59	31
III-B	48	1923	16	Molasses 1-2 plus nicotine 1-300	July 12 July 23	23	5
IV-B	47	1923	14	Molasses 1-2 plus nicotine 1-300	July 23	43	12
Check on II	50	1918	28	(Not sprayed)	--	88	63
II-B	50	1918	26	Molasses 1-2 plus nicotine 1-300	July 13 July 22 July 26	20	5
Check on I	50	1913	58	(Not sprayed)	--	84	
I-A **	50	1913	62	Molasses 1-2 plus nicotine 1-300	July 14 July 22	56	

* Stage of insects on dates of spraying:
July 12-14: moths and eggs abundant; young larvae scarce.
July 22-23: moths scarce; eggs abundant; young larvae fairly abundant.
July 26: moths very scarce; eggs becoming scarce; young larvae abundant.

** Only terminals and upper branches sprayed to protect terminal shoot.

Spraying with molasses alone apparently had no influence on any stage of the insect, as indicated by the infestation in Plot III-A compared to unsprayed trees of the same age in Table 10. The addition of nicotine 1-300

furnished considerable protection in the other plots. The single spray in Plot IV-B, after the adult moths had become scarce, implies that mortality in the egg or larval stage was the cause of lessened damage. Two or more applications, with nicotine added, gave greater reduction in infestation. The egg stage is without much doubt the principal one affected by this spray. That many young larvae were trapped seems unlikely when we remember that the molasses lasts but a few days at the most.

Eggs dipped in molasses diluted 1-2 in the laboratory showed 26 per cent killed, but, of course, the material did not dry up rapidly and conditions in the field were still more favorable for hatching. Molasses with nicotine 1-300 and nicotine 1-300 added killed from 96 per cent to 100 per cent of the eggs in different tests. The checks for these egg tests showed the usual high per cent of fertility.

SEASONAL HISTORY OF TIP MOTH AND DAMAGE 1926

The first adults of Rhyacionia frustrana bushnelli were taken in the field on April 2, 1926, following two days of exceptionally warm weather. This is the earliest recorded emergence, the first moths being taken from four to eight days later in previous years. However, this early first emergence did not assure rapid seasonal development of the spring brood because there followed nearly three weeks of chilly weather unfavorable for further activity. Not until the first week in May was the height of emergence reached.

Pupae were found in the tips on June 17 and second-brood adults are recorded from cages in the laboratory on July 2, and in the field July 3. This is a few days earlier than in 1927, but over a week later than in 1926. The first appearance of second-brood moths has varied as much as 12 days in different years. By the last of August only about half the larvae had left the tips, while in some seasons all larvae have dropped to the ground by August 30.

Even third-brood moths occasionally emerge. On September 22, 1926, September 5, 6, and October 4, 1927, individual moths emerged from material in the laboratory.

Tip moth damage continued about as heavy as in previous years. Usual records of damage and growth were made in the fall for most of the permanent plots, but these data will not be summarized in this report. The severity of the attack is shown by one plot of 100 trees in 1918 yellow pine with 85 per cent of all terminals and 71 per cent of all laterals infested by tip moth larvae during the 1928 season. The first conspicuous dying of a group of trees was noted the past season in a 1912 plantation of yellow pine, a short distance south of the intersection of the Camp 4 and west-boundary roads. Several hundred trees of poor growth at the foot of a north slope have succumbed, most of them within a year, apparently unable to overcome the destruction of new growth each year. Dead trees are occasionally found scattered through the plantations, particularly yellow and Norway pine, but the surprising thing has been the lack of heavy mortality and the ability of these trees to produce

adventitious buds year after year in sufficient numbers to maintain the amount of foliage necessary for their life processes.

RELATION OF TREE HEIGHT TO TERMINAL INJURY

It has been a common observation in yellow pine at Halsey that trees well above sapling height are making a more normal growth than the small trees. To determine to what extent the tip moth still affects these larger trees, an examination was made of the terminal shoots of some 70 of the tallest trees in various plantations. This revealed the fact that the work of the insect was much more prevalent in the tops of these trees than had been suspected. The tallest tree examined, 26 feet in height, had part of the buds on the leader destroyed.

In spite of this continued attack in tall trees, height has a direct influence on susceptibility and amount of damage, as shown by the data presented in Table 11. This table includes the terminal examinations of the trees mentioned above, both 1926 and 1927 attacks being recorded; the trees were planted during several years from 1904 to 1913, and ranged from 5 to 25 feet in height. For smaller trees the past two years' terminal records from two plots in 1915 and 1916 plantings were included, these trees ranging from 1 to 10 feet. The heights have been grouped in five-foot classes.

Table 11

Relation of tree height to terminal injury by tip moth in yellow pine from 10 to 24 years in the field, 1927-1928.

Height class in feet	All terminal shoots		Infested terminals	
	Total No.	% infested	Total No.	Per cent with one or more buds normal
1-5	336	86.3	290	29.0
6-10	94	78.7	74	54.1
11-15	87	74.1	20	50.0
16-20	45	71.1	32	75.1
21-25	34	64.7	22	81.8

Although the susceptibility of terminal shoots to attack decreases only gradually, and more than half of the trees 21-25 feet high are still subject to terminal infestation, the amount of injury decreases appreciably with added height. Above 15 feet the attacked leader has a good chance of having one or more of its buds uninjured. These normal buds will insure the maintenance of this single leader, and the forked and bushy condition, so common in small yellow pine which have the terminal partly or entirely destroyed almost annually, will disappear. This lessened damage in the taller trees might be due to several factors: the increased size of the shoots and buds, a preference for younger trees, and the low flying habit of the moth.

TIP MOTH PARASITES

The abundance of tip moth parasites was followed by the usual method of collecting infested tips at established points in the plantations, referred to as parasite release and collection plots, and rearing the insects from cages in the laboratory. The number of parasites compared to the total number of insects reared, both moths and parasites, gives an approximate percentage of parasitism. A correction has been made in all percentages below for two gregarious species to get a closer approximation of the actual number of larvae and pupae destroyed, and consequently the numbers will vary somewhat from those given in previous reports, particularly for Scotch pine.

Establishment of the Introduced Campoplex

Of several species of parasites liberated at Halsey in 1925, from material brought from East Falls Church, Va., by Mr. R. A. Cushman, and in 1926 from material collected by the writer on Nantucket Island, Mass., only one is known at this time to be definitely established. This species is Campoplex frustraneus Cushman, an internal parasite of the larva belonging to the family Ichneumonidae. A total of 369 individuals of this parasite were liberated between June 27 and July 13, 1925, at a point about one mile out the west-boundary road from the insectary, designated as parasite release Plot V. The number of specimens recovered in 1926, the year following liberation, is not yet certain as identification of material sent to the National Museum at that time has not been received. However, the records show four unidentified Ichneumons reared from Plot V

that year and very likely these were Campoplex frustraneae. One female was obtained from 1926 winter-reared material. By 1927 the establishment of this species was apparent from the unusual numbers reared, and specimens sent to Mr. Cushman were verified as the eastern parasite.

Campoplex frustraneae is better adapted to the tip moth than are the local parasites, its life history being well synchronized with that of the common moth at Halsey. Both have two complete broods each season, the first parasites not emerging until after the peak of moth emergence is past. The height of Campoplex emergence is reached within a week for the summer brood, although the total period lasts more than three weeks. Young host larvae are, therefore, available at the time the parasite appears. Tip moth larvae attacked by this species complete their development and pupate. The parasitic grub spins its white cocoon within the shattered pupal skin of the host. In the overwintering brood the cocoon is not spun until spring just prior to pupation. Thus adults emerge in the spring from tip moth cocoons spun in the sand or litter by second-brood larvae the previous fall. This habit is an important adaptability of Campoplex.

Increase of Campoplex since Introduction

Following the first recovery of the introduced parasite in 1926 there was a very decided increase by the summer of 1927, the number reared from the original release plot far exceeding the usual small number of all local parasites. In 1928 the increase continued, parasitism running over 50 per cent with a noticeable reduction in the number of second-brood moths.

Considering the number of individuals the increase was not proportionately as great in 1928 as in 1927, if the rearings from 300 tips can be used as an indication of abundance. Table 12 shows the yearly increase of Campoplex in the plantation where liberated, also the abundance of local parasites and moths reared from the same tips.

Table 12

Yearly increase of Campoplex in yellow pine at place of liberation, release Plot V, 1925 to 1928, showing influence on per cent parasitism and moth abundance.

Year	No. tips collected	No. of Campoplex	No. local parasites	No. of moths	% parasitism all parasites	% of all parasites Campoplex
1925	300	(Introduced)	30	213	12.3	0
1926	300	4(?)	20	432	5.3	16.7
1927	300	66	13	332	19.2	83.5
1928	300	178	16	163	54.3	91.8

The smaller number of local parasites the last two years at the Campoplex release plot might appear to be caused by parasite competition but this difference is perhaps due largely to the variation that is found in separate lots of tips. This variation is evident the first two years, as shown in Table 12, before Campoplex became a factor, and was even greater in some of the other collection plots. As yet there is no consistent reduction in the local parasites where the new species is abundant. In plantations where growth is very poor the number of moths is often much below the average and this in consequence may also affect the per cent of parasitism.

Spread of Compsilura from Liberation Plot

Compsilura is not only multiplying in the plantation where first liberated but is showing a consistent spread from this point. While the only recovery in 1926 was at the release plot, by 1927 single specimens were reared from two lots of tips collected 7/8 mile distant, and in 1928 single specimens from two lots of tips collected 2 and 2½ miles from the original point of release, with corresponding abundance at shorter distances. The extreme spread was doubtless greater than the above figures which represent rearing from a sample of 300 tips for each collection, and the parasite had to be sufficiently abundant to be found in this small number of tips. The greatest spread seemed to be to the southwest.

By 1928 the new parasite had influenced the per cent of parasitism in practically all of the collection plots within 1½ miles of the center of distribution, working on the host in all tree species. This general spread and increase in parasitism the past two years is shown in Table 13, using yellow pine collection plots within quarter-mile intervals from the original release plot as an indication of distribution.

Table 13

Spread of Campoplex from original release Plot V as shown by abundance and increased general parasitism in yellow pine collection plots at various distances, 1927-1928.

Year	No. collection plots	No. infested tips coll.	No. Campoplex per 100 tips	% parasitism all parasites	% all parasites Campoplex
		Plot V (Original release plot)			
1927	1	300	22	19.2	83.5
1928	1	300	99.3	54.3	91.8
		Plots within 1/4 mile radius of Plot V			
1927	1	200	5.5	7.1	94.7
1928	2	600	52.8	50.8	80.5
		Plots 1/4 - 1/2 mile radius of Plot V			
1927	5	800	4.0	13.7	21.9
1928	5	1100	23.5	29.9	67.2
		Plots 1/2 - 3/4 mile radius of Plot V			
1927	4	1000	1.0	7.8	11.1
1928	3	900	10.8	16.5	50.5
		Plots 3/4 - 1 mile radius of Plot V			
1927	5	1100	0.2	8.0	1.6
1928	4	1000	4.1	14.5	18.8
		Plots 1 - 1½ miles radius of Plot V			
1927	1	300	0	4.9	0
1928	2	600	2.2	13.7	15.1
		Plots 2 - 2½ miles radius of Plot V			
1927	0	--	--	--	--
1928	2	600	0.3	10.1	2.1

Parasitism in Different Tree Species

That parasitism has continued higher each year in Scotch and jack pine than in the species with larger tips is shown in Table 14. The collection plots included were all within about 1½ miles of Compsilura release Plot V, and the influence of the introduced species the last two years is shown by its per cent of the total number of all parasites and the increase in general parasitism. The total number of reared insects for each 100 tips indicates roughly the abundance of larvae in the tips of each tree species. Corrections have been made for two gregarious parasites, as mentioned previously, to make each parasite account for approximately a single destroyed larva or pupa.

Table 14

Abundance of insects, per cent parasitism and influence of Compoplex, as shown by rearings from tip moth infested tips in various species of pine, 1925 to 1928. All plots within 1½ miles of original Compoplex release plot.

Year	No. collection plots	No. infested tips collected	Total insects per 100 tips	% parasitism all parasites	% all parasites Compoplex
		Norway Pine			
1927	2	600	102.5	6.0	2.7
1928	2	600	150.3	19.2	61.3
		Western Yellow Pine			
1925	3	600	101.6	11.1	0
1926	19	3500	101.3	9.6	1.2
1927	17	3700	128.9	9.9	25.6
1928	17	4500	126.8	25.7	61.6
		Jack Pine			
1925	1	200	86.0	36.0*	0
1926	5	800	27.9	24.7	0
1927	5	1000	79.0	26.3	1.4
1928	5	1000	73.8	41.6	41.4
		Scotch Pine			
1926	3	600	37.7	26.8	0
1927	3	600	59.7	22.9	3.7
1928	3	600	74.3	43.9	19.9

* (Takes into account an estimate of 10% of the moths emerging before jack pine tips were collected; therefore, possibly inaccurate).

It will be noticed that in jack and Scotch pine the average number of insects would indicate less than one larva in each infested tip, but this may be accounted for by the death of some insects due to handling the material, and also to the fact that these small tips are occasionally found

empty but cannot be distinguished from the others at the time of collection. The proportionately small number of insects in 1936 may have been partly due to the poor type of cage (Mason jars being used), because the infestation as indicated by counts on trees was equally as heavy as during the other years.

Notes on Local Parasites

At least 17 different species of parasites and one predacious beetle have been reared from tip moth material at Halsey, Nebr. Most of these were presumably present in this locality, attacking other insects, before the plantations were established. Two are possibly secondary parasites. The abundance of the tip moth host material has not resulted in a general increase in the abundance of local parasites as might be expected. These native species are apparently not well adapted to the tip moth, and most of them either fail to attack the second brood or are not able to overwinter with this host and apparently must depend on ~~the~~ other hosts. From tips collected in the fall before the larvae drop out, and from which the insects are reared during the winter, very few of the parasites are recovered, usually a few Braconids only; several other species have emerged in the fall before cold weather, but these are scarce. Some of the common first-brood parasites are not recovered from the second brood, and pupal parasites doubtless have no opportunity to again attack this stage, since the larvae spin up and pupate in the sand or litter.

Haltichella rhyacionias, a Chalcid parasite of the pupa, has been the most abundant solitary parasite reared from the first brood each year, except in 1925 when Eurytoma tylodermatis, a Chalcid parasite of the larva, was reared in equal numbers from the small amount of tips collected that year -- this, of course, disregards the introduced Compsilura. Eurytoma has been less numerous than some others since that time. Microbracon variabilis, a Braconid, is usually fairly abundant and is considered as a solitary species although its habits are not known, and from the numbers emerging at intervals it appears that it might be gregarious. Microbracon sellitor, a solitary species, is very similar to variabilis, especially the males, and, therefore, the two are not readily separated. The gregarious Braconid, Microbracon gelechiae is usually not numerous. Of the Ichneumonidae the pupal parasite, Itoplectis conquisitor, is most important, followed by the internal larval parasite Cremastus geometrae. An egg parasite attacked about 29 per cent of the first-brood eggs in 1926, from indications of rearings from 134 eggs collected between April 23 and May 23, and is the highest per cent so far noted. The identity of this egg parasite has not been determined.

The small gregarious Bethylidae, Goniozus longicorns, has a preference for the host in jack and Scotch pine, being more common than usual in 1926 from certain lots of Scotch pine tips. As many as 10 adult Goniozus have been reared from a single tip moth larva, the small whitish grubs found feeding externally on the host. It might be

interesting to note here that some of these little parasites have lived for a full year. Nine of them reared the last of July, 1927, were kept in a four-inch shell vial and fed honey and water; one died in August, the others being placed outside when the laboratory was closed in late October. The following April three were found alive among the paper strips, several of the others having been caught in the sticky sugar left in the vial. Fresh food was again supplied and one individual lived until the first of August, 1928. Specimens of Microbracon sellitor and M. gelechiae were kept under similar conditions for 15 weeks, Habrobracon 13 weeks, Eurytoma 12 weeks, and were still alive when placed outside in late October, but all were found dead the following April. The more active Ichneumons died much sooner, although one Campoplex lived for 67 days with food supplied.

To compare the percentage of parasitism from only the local parasites with that of previous years, all larvae attacked by Campoplex might be considered as otherwise producing adult moths. This is perhaps not entirely accurate but, nevertheless, is a close approximation as there is little evidence as yet of a decrease in the local parasites due to competition. Table 15 shows the per cent of parasitism from the local species and the consistent difference in various tree species for the past four years.

Table 15

Per cent parasitism by local parasites in different species of pine, 1925-1928; considering the introduced Campsolex as potential moths.

Year	Per Cent Parasitism			
	Norway Pine	Western Yellow Pine	Jack Pine	Scotch Pine
1925	—	11.1	36*	—
1926	—	9.5	24.7	28.8
1927	5.9	7.4	25.9	22.1
1928	7.4	9.9	24.4	35.2

* (Number of moths emerging before tips were collected estimated at 10%).

INSPECTION OF PRIVATE PLANTATIONS

New Plantings

A short trip was made with Mr. Clayton Watkins, State Extension Forester of Nebraska, about the middle of August, to inspect some of the small plantations put out since the dipping of nursery stock was begun in 1927. Of 12 plantings inspected in Lincoln and Dawson Counties, ten were from the 1928 shipments, one from 1927, and one containing trees received the last three years. Survival varied greatly and was in direct proportion to the care given the trees. In no case was there evidence of chemical injury due to treating the nursery stock; furthermore, these small trees were free of any tip moth infestation. Several old plantations examined in this region were infested, however.

So far we have little knowledge of the habits of dispersion of the tip moth outside of its transportation on nursery stock. It is possible that these clean plantations of young stock will also be infested in time and an inspection after several years might give us some evidence as to whether there is a general distribution by flight.

Old Plantations

The thorough distribution of the tip moth over the Kinkaid District in Nebraska was evidenced by its presence without exception in some 15 old, private plantations examined during the summer in widely scattered localities. These isolated plantings ranged in age from about 8 to 30 years, and were distributed from near the native timber in northern Nebraska to the Platte River Valley south of the sand hills. The damage by the pest varied from a negligible amount in old jack pine to serious retardation of growth in smaller yellow pine. The tip moth is also common in native trees along the Niobrara River; the nearest native western yellow pine to Halsey probably being that in a tributary canyon north of Johnstown, Nebr., some 50-60 miles by air line north of the Forest.

OBSERVATIONS ON TWO TIP MOTHS NEW AT HALSEY

A few specimens of two species of moths have been taken in the plantations in early spring for several seasons. Material sent to Mr. Heinrich of the U. S. National Museum last spring was determined as Rhyacionia neomexicana Dyar and Rhyacionia adana Heinrich. The

former has been recorded prior to this time only from the Southwest, not north of southern Colorado. A single moth of this species was also reared from Black Hills, South Dakota, material in 1926 and the determination verified by Mr. Heinrich. The common moth in the Black Hills is, however, H. frustrana bushnelli, but in this region it has only a single generation each year. Larvae examined in native yellow pine in northern Nebraska the past summer indicated that H. neomexicana is also present in this area.

Physcionia adona is an eastern species known only from field-collected specimens taken in Virginia, Pennsylvania and Massachusetts, according to Heinrich.

Physcionia neomexicana Dyar.

This species is about half again as large as the common moth, H. bushnelli, having a wing expanse of 19-25 mm., and the forewings instead of being a mottled red and brown are mostly gray with only the outer third at the tip a light reddish color with several horizontal black streaks. The first specimens of this moth were taken in the field at Halsey on April 28 and 29, 1926; in 1928 a few were also taken on April 26 and May 1. The adult moths emerge in the spring about the same time as the common moths, although from material being reared in the laboratory this winter the first moths emerged two days ahead of H. bushnelli. There is but a single generation each season at Halsey.

The eggs of H. neomexicana are more reddish and slightly larger than those of the more common moth. The yellowish larvae usually have

a distinct reddish tinge and a black spot on the last abdominal segment; when full grown the larvae are readily distinguishable by their greater size. The larvae begin dropping from the tips, to spin up in the sand and litter, about the time second-brood adults of N. bushnelli begin to emerge in late June and early July.

The damage by this moth was sufficiently abundant the past season to be noticeable in some of the trees and is evidently increasing. While the first brood of N. bushnelli usually injures little more than the buds the work of the larger species is much more destructive, and resembles the heavy damage of the second brood, short shoots often being completely riddled and the amount of frass in the pitchy webs at the base of the needles conspicuous. Sometimes the larvae begin work on the side of the shoot rather than near the apex, and this may cause the shoot to bend slightly. So far this species seems to be confined to the older plantations; no larvae could be distinguished in 1918 or younger plantings. Where most prevalent above the nursery an examination of 100 trees gave evidence of these larvae in, roughly, 15 per cent of the terminals, the common moth infesting some 5½ per cent. Jack and Scotch pine are also attacked but yellow pine is preferred.

Rhyacionia adams Heinrich

This species is only slightly larger than N. bushnelli but resembles N. mexicana in color, being mostly gray with only the tips of the forewings reddish. The first moths recorded from Halsey were taken over the nursery beds April 6 to 9, 1927, before the common moth was seen in the field. In 1928 specimens were collected in the field

on April 2, the same day the first of the common species were taken. Moths have only been found in early spring, as noted above, indicating but a single generation. The host plant of the species has not been recorded but presumably it works on pine as do the other species of the genus. There has been no opportunity to trace its habits since its identification with this group last summer.

OTHER INSECTS IN PLANTATIONS AT HALSEY

Forest insects of various types are being found in the plantations at Halsey and some of these have apparently been present for several years. The status of those which have been identified will be given below.

Pitch Moths

Two species of pitch moths have now been identified from material recently sent to Washington, Pinipestis sp., and Dioryctria ponderosae Dyar. As mentioned in last year's report pitch moth work has been found in all parts of the plantations where trees are large enough to attack — the boles of yellow pine four feet high are sometimes infested. The damage to yellow pine has not become particularly serious, although branches and tops are occasionally found killed by girdling. The principal damage is the girdling at the base of branches and the upper bole at the whorls on older Scotch pine, causing death of these parts or breaking in heavy winds. Austrian pine is also injured considerably in this same way. Jack pine is only occasionally attacked. The presence of the larvae is indicated by conspicuous pitch exudations.

The experimental control in some of the older Scotch pine plantations in 1927, by cutting out the pitch moth larvae, had a favorable effect on the intensity of infestation in 1928 in these trees. The 1913 plantation above Block III of the nursery had 52 per cent of all trees infested before the experiment with from 1 to 45 larvae, an average of 6 larvae per tree, whereas the following year only 33 per cent of the trees were infested, with an average of about 2 larvae for each attacked tree. The operation was rather expensive, $12.71 per acre, and it was estimated that 88 per cent of all larvae was destroyed. It seems that the prevalence of moths found in other plantations will soon minimize the benefit resulting from the experiment.

Another type of injury showing particularly in Austrian pine has been attributed to the pitch moth. A large number of trees in a plantation on the west-boundary road were conspicuous with dead tops and laterals last spring, and when examined with Dr. Craighead in June it was found that most of these had been partially girdled by this pest anywhere from one to four years previously. Dr. Craighead stated that the cause of death of the parts above the scars was comparable to "red branch" of fir. In fir, twigs gnawed on the underside by a Monochamus in feeding die in numbers during the next severe winter, due to excessive drying of the tissue. The winter of 1927-28 at Halsey was probably unusual enough to similarly affect the Austrian pine shoots.

The pitch moth is found in native yellow pine along the Niobrara River. Besides its usual work on the bole of the tree, it is often

found working in Peridermium galls, which is also a common occurrence in the plantations. Larvae of this insect were found in widely-scattered private plantations last summer; at several points between Halsey and the Niobrara River, also in Holt County, and in Scotch pine at the Agricultural Experiment Station in the Platte River Valley in southern Nebraska. All of these plantations contained either yellow or Scotch pine, but no evidence of the pest was found in the old, pure jack pine plantations.

At least two Ichneumonidae are known to attack the pitch moth at Halsey; one spinning its cocoon within the cocoon of the host in the burrows and emerging in late August; the other wintering over in the host and emerging from the pupal skin in late May. Parasitism has not been found very heavy.

Barkbeetles

Examining, with Dr. Craighead in June, the group of dead 1912 yellow pine saplings mentioned previously under discussion of damage, the first barkbeetles recorded in the Keesey plantations at Halsey were found. Specimens were sent to Dr. H. F. Blaisdell for identification. The common species was determined as Orthotomicus caelatus Eich.; single specimens of Hylurgops porosus Lec. and Ips sp. (possibly a new species found in Colorado and New Mexico) were also found in the collections.

Apparently the beetles had attacked only dying trees which had succumbed to the ravages of the tip moth. Several trees were found with a living branch or two just above ground line, but no green tissue was evident above this point, the remainder of the tree being entirely dead.

Egg galleries were constructed between the bark and the wood on the bole, with a few running along the base of branches. Pupa cells of the Orthotomicus were usually made in the wood, although some were also found in thicker bark. The time of attack is not yet known, but in late June larvae, pupae and adults were all found in the trees. Some of the bark beetles have been present for at least several years because a few scattered dead trees were noted with empty galleries and appeared to have been dead for sometime.

Scale Insect

Early last spring Supervisor Higgins discovered a heavy infestation of a scale insect in jack pine about two miles from the nursery. Specimens were identified by Dr. H. Morrison (from description only) as Toumeyella numismaticum Pett. and McD. The infestation covered several acres in an old 1909 jack pine plantation and the adjacent 1916 plantation. Some of the younger trees were succumbing to the heavy attack and the others making poor growth. Late in May Mr. Higgins had all infested trees cut and burned and has apparently eradicated the pest.

The scale is globular in shape, about 1/8 inch in diameter, black and reddish in color and works on the newer shoots among the needle bases. Attacked trees take on a characteristic sooty appearance, presumably from a fungus that thrives in the honeydew. Birds must have brought the pest into the Nebsey plantations.

Mr. Higgins reports that this scale has been present in some of the old jack pine plantations of Holt County, northern Nebraska, for

many years, and trees have been killed. Some of these plantations were visited last summer and the heavily attacked trees were found in a serious condition. A record in the Washington Office shows that the insect has been found much nearer Halsey. In March, 1916, former Supervisor Johnson sent in specimens taken from the 13-year-old plantation of F. G. Beckhoff, Thedford, Nebr., and these were identified as "probably pini" but is the same species as given above.

It is not at all unlikely that the scale will appear again in the plantations, or may even now be working in some isolated place. However, if such epidemics are found while still very localized, they can be eradicated. An unauthenticated statement reports that the scale has recently appeared in the Bruner plantation, the original demonstration planting in the sand hills instigated by Dr. Bessey in 1891. It is an exceedingly difficult task to induce these private owners to eradicate the scale -- and with it most of their trees -- and there is no authority to compel such a protective measure.

Cone Moth

Some of the oldest yellow pine have only recently started to produce a few scattered cones. A few of these cones examined on August 25, 1923, were found infested by a cone moth. The adults had already emerged and only the empty pupal skins were found in the burrows. Presumably the moth is Dioryctria xanthenesbares Dyar, this species being reared from cones collected in native yellow pine near Valentine, Nebr., last summer, the adults issuing between July 21 and August 10.

In undeveloped cones from the same native pine near Valentine a cone beetle was also found and identified by Mr. Blackman as Conophthorus ponderosae Hopk. This beetle has not been found at Halsey, although there has been no opportunity to make a careful search for it.

GENERAL DISCUSSION AND RECOMMENDATIONS

Since Volck, the white oil emulsion, provides the cheap dip that has been sought for treating nursery stock, the intensive experiments along this line may now be discontinued. A few tests to determine the loss of oil in the dipping tank from absorption might be continued, and any other insecticide that looks equally as promising as the white oil should be given a trial if the other work permits.

The advisability of treating all nursery stock shipped to the Niobrara Division of the Forest has been considered. As long as this stock is planted adjacent to previously infested areas this precaution, it seems, would be of little value because the spread of the tip moth would doubtless cover this area within a few years. Furthermore, damage by tip moth is negligible the first two or three years, and presumably protection from this initial injury only would be obtained by destroying all eggs carried on stock from the nursery.

Examination of yellow pine planted the past spring on the 1927 burn at Halsey, adjoining heavily infested 1922 plantings, showed that trees the first year in the field are unfavorable for attack. Out of 1,500 new trees planted among and within a few hundred feet of the older infested trees only 0.2% per cent contained larvae or damage from the

first brood and 1 per cent from the second brood. This is probably partly due to the poor condition of growth the first season. There were also indications that ground insects might have removed some larvae. Examination of 2,000 similar trees in the Camp 4 area, not immediately adjacent to infested areas, revealed no indications of tip moth, although in 1925 one tree in 2,000 examined, or 0.05 per cent, showed evidence of tip moth the first season. From plot records the number of trees attacked the second year in the field in yellow pine is about 1.5 per cent, the third year 13.5 per cent, and about the eighth year all trees are infested. In jack pine, which is much taller than yellow pine of the same age, the infestation increases at a more rapid rate, and by the fifth year 100 per cent of the trees are attacked, although the per cent of tips injured is much smaller than in the other species.

If it was certain that the infestation in each year's plantings originated chiefly from the nursery, the treatment of Niobrara stock might delay the entry of the moth for several years and be well worth while. With our present uncertainty of this fact the cleaning of Niobrara stock, if undertaken, would have to be considered as an experiment to determine definitely what protection was afforded. The present infestation on the north Division is serious, though possibly not quite as heavy as at Halsey. Of 500 terminals examined on yellow pine in the Niobrara plantations, 36 per cent were hit by the first brood, while in the Nenzey plantations 200 trees of a comparable age had 48 per cent injured — if these limited observations can be considered a criterion to the situation. In the event of an isolated

plantation being started it would be advisable to clean the comparatively small amount of stock shipped to the north Division in an attempt to keep out the tip moth.

Experiments with dusting and spraying in the field indicate that the egg of the tip moth is the one stage particularly exposed to insecticide applications. Any of the ovicides found efficient as dips would doubtless prove fairly effective as sprays for larger trees. Therefore, Volck 1-100, because of its cheapness and effectiveness, should be tested in the field next summer. On account of the long period of moth emergence several applications would be required. For instance, most of the second-brood moths emerge within a period of three weeks, the eggs hatching from 5 to 10 days from oviposition, consequently three applications of an insecticide at six-day intervals after appearance of the first moths should catch practically all eggs before hatching. Eggs from the first-brood moths are commonly found on the inner surface of the needles, some are also deposited on the bundle sheaths and expanding shoots, and for the second brood on the bud scales of the completed new growth also. Consequently these surfaces in particular should receive a thorough wetting by the spray. An efficient spray, used as an ovicide, would be of value in protecting small plantings from severe injury, and could also be applied to individual trees that have an ornamental value.

Within the last few years the general egg parasite, Trichogramma pretiosa Riley, has been experimented with in different parts of the country as a possible means of biologically controlling the codling moth and the sugarcane borer. As a result a technique has been developed for rearing this species in enormous numbers from the eggs of the Angoumois grain moth. Mr. Craighead is negotiating for a supply of this material from one of the eastern laboratories for an experiment with control of the first-brood tip moth on a small area at Kelsey. The Trichogramma parasites should be liberated during the height of moth emergence when eggs are most abundant, or even shortly after, as these eggs will not hatch for at least two weeks in early May. Since this period has varied in different years from April 20-25 to May 1-7, it seems safe to plan for the liberation to start at an intermediate date, or the last few days in April, if the parasitized host material is obtained.

That spring climatic conditions are not unfavorable for such delicate insects is evidenced by the fact that the present egg parasite attacks tip moth eggs in late April and during May. Specific determination of this minute species has never been received, but it is not unlikely that it is Trichogramma. Its ability to increase effectively is no doubt limited by the scarcity of host material during several generations that occur between the laying of first and second-brood tip moth eggs; the life cycle of the parasite appears to be only a few days longer than the incubation period of tip moth eggs at any given time of the season. This indicates that liberation of quantities of this species

might only influence the particular brood present at the time and not result in a permanent increase in parasitism, although it might prove otherwise. However, the reduction of a single brood would not only lessen damage to trees at the time but the remaining larvae could be more effectively reduced by the other parasites. If the experiment proves that quantity liberation of Trichogramma is effective, this method might be used to augment the work of the introduced larval parasite Compoplex, and thus reduce the several years required for its gradual increase to a beneficial abundance.

For the liberation experiment the 1918 plantation of yellow pine along the west-boundary road would be most suitable for the following reasons: damage is exceptionally heavy and previous years' damage have been recorded; trees are small enough to permit thorough examination; the stand is extensive enough to establish comparable check plots; the introduced larval parasite Compoplex will not be a factor in this area by next spring; and the area is readily accessible by car.

The encouraging increase of Compoplex frustranea makes it advisable to introduce this species into the isolated Camp 4 plantings at Halsey and also the Niobrara Division as soon as possible. The necessity of liberating large numbers at scattered points to eliminate the slow building up and spread is quite obvious. On the Camp 4 area a large quantity of tips could be caged in different plantations and Compoplex thus started at widely separated points. Pasteboard boxes with an opening covered with 14-mesh screen to retain the moths, and protected from rain by roofing

or other paper, might serve this purpose. The large open type of cage with the tips dumped on the ground is not entirely satisfactory since the material is subjected to extremes of temperature and moisture as well as the ravages of ants. The collection of tips, if necessary, can be delayed until after the regular parasite rearings are under way, as Campoplex does not begin to emerge until from 9 to 14 days after the first moths appear. Local parasites may be disregarded, since their ineffectiveness from concentration has been shown, and the tips collected in areas where Campoplex is most abundant. The method of liberating the parasite on the Niobrara Division and the quantity will depend on the availability of an assistant next season. The adults might be shipped from Halsey if suitable containers can be procured or devised.

Parasite material collected on the Niobrara Division showed that conditions were similar to those at Halsey as to species and abundance of parasites. The moths had started to emerge before the tips were obtained, and therefore accurate figures on percentage of parasitism cannot be given. From material collected in native timber only, several miles north of one of the Niobrara planting sites, parasitism was possibly a little higher, but several of the common parasites found in the plantations, Baltichella and Eurytoma, were unusually scarce.

The study of tip moth parasites will be followed again next summer. In fact this study should be pursued for a number of years, even if it is necessary to handle it in addition to work on other projects, since the Halsey situation offers an unusual opportunity to follow the progress and

final effectiveness of an introduced parasite on one of our forest pests.

It is impossible to predict the ultimate status of the introduced parasite Exoryplex frustraneae, but its continued increase looks very favorable at this time. The inaccessibility of a small per cent of larvae in the larger tips would tend to minimize the prospective efficiency of the parasite. The reproductive potential of Exoryplex as compared to that of the tip moth will largely determine the ability of the parasite to hold the host in check. Secondary parasites may in time also play an important part in the activity of this species.

Further work in Arizona, with the object of introducing parasites that might be well adapted to attacking the host in yellow pine and also parasites working on Dioryctria mesoxicana, will depend on obtaining an assistant familiar with the work at Halsey, as well as the amount of funds available. Winter rearing from the Arizona and Colorado parasite material has not been completed and therefore the data cannot be summarized at this time.

It now seems likely that practically all forest insects found in native yellow pine in northern Nebraska will eventually find their way into the plantations at Halsey. The advisability of recording these insects and watching their reaction to such an environment as the extensive stands of young pine in the plantations is quite obvious. Collections and observations should be made at every opportunity in the native timber to facilitate the detection of possible epidemics.

In time, when the planted areas assume natural forest conditions, many of the insects will doubtless be taken care of by factors controlling them in other forests. The vigor and fast growth in young trees is in itself a source of immunity to serious injury by certain insects. This is particularly apparent with tip moth damage to western yellow pine in the plantations. Fast-growing individual trees are making height growth in spite of continued injury because the long terminals have only a small proportion riddled by larvae and the intact length is continued the following year by an adventitious shoot if necessary, while the individuals with less vitality put out only short tips which are often completely destroyed. No evidence of immunity to attack has been found in individual yellow pine trees. Certain species of pine subject to attack may have specific immunity to a high degree, as is the case with Austrian pine which is only slightly injured.

The present experiments by the Forest Service in selecting seed for Nebraska planting, both as to climatic requirements and qualities of the parent tree, may in time prove to be a source of protection from destructive forest insects. The expected increased vigor of the individual tree may in itself be the factor of immunity from attack of certain pests, while the vigorous growth will be a source of protection from excessive damage by such insects as the tip moth.